REMARKS

Remailed Office Action

The Applicant wishes to thank Examiner Mull and Supervisory Primary Examiner Tarcza for their initiative and effort in having the Notice of Abandonment vacated and having the Office Action re-mailed.

Information Disclosure Statement

The Applicant regrets any inconvenience to the Examiner due to copies of documents from Information Disclosure Statement missing when considered by the Examiner. The file of the undersigned indicates that the documents were submitted. Nonetheless, the Applicant wishes to thank Examiner Mull for his effort in obtaining a copy of the Teunissen reference.

Submitted herewith is a copy of the other reference, which was not readily available to the Examiner: "U. Vollath, Decentralized Floating Solution in Trimble Total Control 2.7, Trimble Terrasat GmbH Internal Report, Issue 1, Revision 1, unpublished (7 pages)." The Applicant respectfully requests consideration of this reference.

Allowable Subject Matter

The Applicant wishes to thank the Examiner for the indication of allowable subject matter, and respectfully submits that amendment to overcome the rejection(s) under 35 USC 112, 1st paragraph, are not needed for reasons given below.

Claim Amendments

Claims 11, 16, 23, 33, 34 and 36-38 are amended to correct obvious typographical errors. No new matter is introduced by the amendments.

Claim Rejections – 35 USC §112

Claims 1-49 stand rejected under 35 USC §112, first paragraph, as failing to comply with the enablement requirement. The Office Action states:

> 3. Claims 1-49 rejected under 35 U.S.C. 112, first paragraph, as failing to comply with the enablement requirement. The claim(s) contains subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention.
>
> The claims include a limitation to Quintessence filters (claim 1, p. 61, line 13; claim 23, p. 63, line 34). However, the definition of "Quintessence" or "Quintessence filter" is not given, nor is the structure of a Quintessence filter shown. It is noted that while Fig. 11B "shows a generalized structure in which a plurality of Quintessence filter banks is provided in accordance with embodiments of the invention" (p. 8, lines 21-22), the structure of Quintessence filter bank is simply shown in terms of Quintessence filters, with no internal structure of the Quintessence filters shown. This term does not appear to be used in the art, so one of ordinary skill would not know what a Quintessence filter is in order to implement the claims.

The Applicant respectfully disagrees and hereby requests withdrawal of the rejections.

An applicant is permitted to use his own terminology, so long as it is understood. The description is a dictionary for the claims and provides clear support or antecedent basis for all terms used in the claims. Manual of Patent Examining Procedure §§608.01(g).

The terms "Quintessence" and "Quintessence filter" are not known to the Applicant to be terms previously used in the art, and were for this reason selected to refer to the novel filters first conceived, described and claimed by the Applicant. The structure of the claimed Quintessence filters is defined in the specification in a manner sufficient to enable one of skill in the art to make and use the claimed invention.

In the following, attention is directed to the table of notations found at page 12 of the application, corresponding to paragraph [0083] of the published application.

The purpose and function of the Quintessence filters is given at page 14, lines 24-31 of the application, corresponding to paragraph [0092] of the published application:

> [0092] FIG. 11A shows structure of a Quintessence filter bank 1100 in accordance with embodiments of the invention, for a number ns of observed satellites. **Quintessence filter bank 1100 includes a respective geometry-free and ionosphere-free filter 1105, 1110, . . . 1115, each filter corresponding respectively to one of the observed satellites** Sat1, Sat2, . . . Satns. Each filter is applied to the GNSS signal data for the corresponding satellite and supplies the result to a double-differencing element 1120 **to obtain an array 1125 of ambiguity estimates for the geometry-free and ionosphere-free carrier-phase combination and associated statistical information.** ***

Formulation of geometry-free filters including those used for the Quintessence filter banks is given at page 21, line 22 – page 22, line 24 of the application, corresponding to paragraphs [0146] – [0161] of the published application; filter initialization is given at page 22, line 25 – page 23, line 25, corresponding to paragraphs [0162] – [0171] of the published application; and a specific implementation is given with reference to a textbook on the subject at page 23, lines 27-29, corresponding to paragraph [0172] of the published application:

> Geometry-Free Filters
>
> **Geometry-free filters used for the ...Quintessence filter banks, such as filter banks ... 840(1)...840(*nf*-2) ... will now be described. They implement estimating the ambiguity of a given geometry-free observable combination $\bar{a}$ accounting for uncorrelated noise and correlated noise with a given correlation time.**
>
> Kalman Filter Formulation
>
> A geometry-free filter in accordance with embodiments of the invention is implemented as a Kalman filter with two states. The first state (N_f) is the ambiguity state to be estimated. The second state (vc_k where k is the current epoch) models the time-correlated error component (state augmentation) with an exponential time-correlation (Gauss-Markov(1) process).

The defining formulas for the Kalman filter (according to A. GELB (ed.), *Applied Optimal Estimation*, The M.I.T. Press, 1992. pp. 107-113) are:

State vector:

$$x_k = \begin{pmatrix} N_f \\ vc_k \end{pmatrix} \tag{0.1}$$

State transition matrix:

$$\Phi_k = \begin{pmatrix} 1 & 0 \\ 0 & \frac{\sigma_k}{\sigma_{k-1}} \cdot \left(1 - e^{\frac{t_k - t_{k-1}}{tc_k}}\right)^2 \end{pmatrix} \tag{0.2}$$

in which the upper left term 1 indicates the ambiguity is constant from epoch to epoch, k is the epoch number of the current epoch, k-1 is the epoch number of the previous epoch, tc_k is the time constant of correlated noise at epoch k, and the exponential term is the assumed exponential temporal correlation (equation 0.2 above).

System driving noise matrix:

$$Q_k = \begin{pmatrix} 0 & 0 \\ 0 & \sigma c_k^2 \end{pmatrix} \tag{0.3}$$

in which the upper left term 0 indicates that the ambiguity state (state 1) is constant statistically, and the lower right term σc_k^2 is the variance of correlated noise (variance of state 2) at epoch k.

Design matrix:

$$H_K = \begin{pmatrix} 1 & 1 \end{pmatrix} \tag{0.4}$$

in which the values 1 and 1 indicate the measurement contains the sum of the ambiguity state (state 1) and the correlated noise (state 2).

Measurement noise matrix:

$$R_k = \left(\sigma u_k^2\right) \tag{0.5}$$

is the variance of uncorrelated noise (white noise) at epoch k.

Observation

$$z_k = \phi_f \tag{0.6}$$

is the carrier-phase measurement of epoch k for frequency f to be filtered.

Filter initialization:

$$\begin{aligned} \hat{x}_1^+ &= \begin{pmatrix} \phi_1 \\ 0 \end{pmatrix} \\ P_1^+ &= \begin{pmatrix} \sigma u_1^2 + \sigma c_1^2 & -\sigma c_1^2 \\ -\sigma c_1^2 & \sigma c_1^2 \end{pmatrix} \end{aligned} \tag{0.7}$$

in which the subscript 1 indicates starting with epoch number 1.

Standard Kalman filter algorithm (for $1 < k \le ne$):

$$\begin{aligned} \hat{x}_k^- &= \Phi_{k-1} \cdot \hat{x}_{k-1}^+ \\ P_k^- &= \Phi_{k-1} \cdot P_{k-1}^+ \cdot \Phi_{k-1}^T + Q_{k-1} \\ K_k &= P_k^- \cdot H_k^T (H_k \cdot P_k^- \cdot H_k^T + R_k)^{-1} \\ \hat{x}_k^+ &= \hat{x}_k^- + K_k \cdot (z_k - H_k \cdot \hat{x}_k^-) \\ P_k^+ &= (I - K_k \cdot H_k) \cdot P_k^- \end{aligned} \tag{0.8}$$

The first two lines of 0.14 serve to time-update the state vector and the error propagation for each new epoch. The last three lines of 0.14 serve to update the measurements for each new epoch.

The first line of 0.14 produces a state vector for the current epoch k by updating the state vector for the previous epoch with the state transition matrix Φ_{k-1} of the previous epoch k-1 (which in turn takes account of the time constant of the time-correlated noise).

The second line of 0.14 produces an error propagation P_k^- matrix (variance-covariance matrix of the state) for the current epoch k by updating the error progagation for the previous epoch k-1 with the state transition matrix Φ_{k-1} of the previous epoch k-1 (which in turn takes account of the time constant of the time-correlated noise) and the system driving noise matrix Q_{k-1} for the previous epoch k-1 (which in turn takes account of the variance of the time-correlated noise).

The third line of 0.14 indicates how the Kalman gain K_k for the current epoch k is related to the error propagation matrix P_k^- (which is in turn a function of the time-correlated noise and its time constant as discussed above) and to the measurement noise matrix R_k describing the variance of the uncorrelated noise. The Kalman gain K_k may be regarded

as a "blending factor" between time updates of old information and new measurement observations.

The fourth line of 0.14 indicates how the updated state estimate for the current epoch k is related to the time-updated state vector for the current epoch, the Kalman gain K_k for the current epoch, and the carrier-phase measurement observed for the current epoch k.

The fifth line of 0.14 is an error propagation matrix P_k^+ (variance-covariance matrix of the state) for the current epoch k

The Kalman filter may be implemented using the Bierman UD-Filter (see G. BIERMAN, *Factorization Methods for Discrete Sequential Estimation*, Academic Press, 1977) or any other numerically-stabilized implementation of the Kalman filter algorithm.

An alternate formulation of Quintessence filter banks is given at page 24, lines 1-15, corresponding to paragraphs [0172] – [0176] of the published application:

Alternate Formulation

In case of uncorrelated errors that are very small compared to the correlated errors, a **simpler filter can be applied** in accordance with embodiments of the invention. See the "whitening of noise" approach in G. BIERMAN, *Factorization Methods for Discrete Sequential Estimation*, Academic Press, 1977, and the "differencing approach" in A. GELB, (ed.), *Applied Optimal Estimation*, The M.I.T. Press, 1977, pp. 133-136. **This applies to the** ionosphere and **Quintessence filter banks.**

Filter initialization:

$$\begin{aligned} a_1 &= 0 \\ q_1 &= 0 \\ \hat{x}_1^+ &= (\phi_1) \\ P_1^+ &= (\sigma c_1^2) \end{aligned} \tag{0.9}$$

Filter algorithm ($1 < k \le ne$):

$$
\begin{aligned}
cor_k &= e^{-\frac{t_k - t_{k-1}}{\tau c_k}} \\
c_k &= cor_k \cdot \frac{\sigma c_k}{\sigma c_{k-1}} \\
l_k &= \phi_k - \phi_{k-1} \cdot c_k \\
v_k &= \left(1 - cor_k^{\,2}\right) \cdot \sigma c_k^2 \\
a_k &= a_{k-1} + l_k \cdot \frac{\left(1 - c_k\right)}{v_k} \\
q_k &= q_{k-1} + \frac{\left(1 - c_k\right)^2}{v_k} \\
\hat{x}_k^+ &= \frac{a_k}{q_k} \\
P_k^+ &= \frac{1}{q_k}
\end{aligned}
\qquad (0.10)
$$

Where c_k is a modified correlation coefficient, l_k is a modified variance (uncertainty), v_k is the uncertainty in the measurement, a_k is accumulated weighted information, q_k is an indicator of certainty with each new epoch (accumulated weights, the inverse of variance), the term a_k / q_k is the ambiguity, and the inverse of q_k is the variance of ambiguity.

The Quintessence filters are further described at page 25, lines 7-10 as using the Quintessence carrier phase combinations, corresponding to paragraphs [0182] – [0183] of the published application:

Quintessence Filters

For nf frequencies, $nf - 2$ geometry-free Quintessence filters, such as in Quintessence filter banks 840(1)...840(nf-2), are implemented using the Quintessence carrier phase combinations $\bar{a}_{Q_i}$. See discussion of Quintessence carrier-phase combinations below.

Properties of the Quintessence carrier-phase combinations are given at page 26, lines 11 – 20, corresponding to paragraphs [0195] – [0200] of the published application:

Coefficient Determination

The following sections describe how to derive the different code and carrier combination coefficients $\vec{a}_f$ for the individual filters.

Properties of the Combinations

The measurement combinations presented in the following have the properties:

- Minimum-error geometric, minimum-error ionospheric and Quintessence combinations are pair-wise uncorrelated;
- Correlation of the code combinations to the minimum-error geometric, minimum-error ionospheric and Quintessence combinations can be neglected as the code multipath is two to three orders of magnitude higher than the carrier-phase multipath.

Error models for the Quintessence combinations are given at page 26, line 21 – page 27, line 1, corresponding to paragraphs [0201] – [0203] of the published application:

Error Models for the Combinations

For every combination $\vec{a}_f$ presented, the error characteristics of uncorrelated noise $\sigma u^2_{\vec{a}_f}$, of correlated noise $\sigma c^2_{\vec{a}_f}$ and time constant $tc_{\vec{a}_f}$ can be computed using the following formulas:

$$\sigma^2_{\phi_{\vec{a}_f}} \approx \vec{a}_f^T \cdot \begin{pmatrix} \sigma\phi_1^2 & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \sigma\phi_{nf}^2 \end{pmatrix} \cdot \vec{a}_f \qquad (0.11)$$

wherein the diagonal matrix carries individual variances per frequency, and

$$tc_f = \frac{\begin{pmatrix} \left|a_{\phi_{nf,1}}\right| \\ \vdots \\ \left|a_{\phi_{nf,nf}}\right| \end{pmatrix}^T \cdot \begin{pmatrix} tc_{\phi_1} \\ \vdots \\ tc_{\phi_{nf}} \end{pmatrix}}{\sqrt{\begin{pmatrix} a_{\phi_{nf,1}} \\ \vdots \\ a_{\phi_{nf,nf}} \end{pmatrix}^T \cdot \begin{pmatrix} a_{\phi_{nf,1}} \\ \vdots \\ a_{\phi_{nf,nf}} \end{pmatrix}}} \qquad (0.12)$$

The Quintessence carrier-phase combinations for an arbitrary number nf of carrier frequencies are given at page 29, line 7 – page 30, line 3, corresponding to paragraphs [0220] - [0223] of the published application:

Quintessence Carrier-Phase Combinations

The Quintessence carrier-phase combinations are used in the Quintessence filters. For nf carrier frequencies, $k = 1, \cdots, nf - 2$ Quintessence carrier phase combinations are defined by:

$$\varphi_{Q_k} = \vec{a}_{Q_k}^T \cdot \begin{pmatrix} \phi_1 \\ \vdots \\ \phi_{nf} \end{pmatrix} = \begin{pmatrix} a_{Q_k,1} \\ \vdots \\ a_{Q_k,nf} \end{pmatrix}^T \cdot \begin{pmatrix} \phi_1 \\ \vdots \\ \phi_{nf} \end{pmatrix} \qquad (0.13)$$

With the following notations:

$$\vec{A}_{Q_k} = \begin{pmatrix} \frac{1}{\lambda_1} & \cdots & \frac{1}{\lambda_{2+k}} \\ -\frac{\lambda_1}{\lambda_1^2} & \cdots & -\frac{\lambda_{2+k}}{\lambda_1^2} \\ 1 & \cdots & 1 \\ a_{Q_1,1} \cdot \sigma\phi_1^2 & \cdots & a_{Q_1,2+k} \cdot \sigma\phi_{2+k}^2 \\ \vdots & \ddots & \vdots \\ a_{Q_{k-1},1} \cdot \sigma\phi_1^2 & \cdots & a_{Q_{k-1},2+k} \cdot \sigma\phi_{2+k}^2 \end{pmatrix}^{-1} \cdot \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \\ \vdots \\ 0 \end{pmatrix} \qquad (0.14)$$

in which the coefficients are defined by:

$$\begin{pmatrix} a_{Q_k,1} \\ \vdots \\ a_{Q_k,2+k} \end{pmatrix} = \vec{A}_{Q_k} \tag{0.15}$$

$$\begin{pmatrix} a_{Q_k,3+k} \\ \vdots \\ a_{Q_k,nf} \end{pmatrix} = \begin{pmatrix} 0 \\ \vdots \\ 0 \end{pmatrix} \tag{0.16}$$

The Quintessence carrier-phase combinations for the simpler case of three carrier frequencies are given at page 32, line 12 – page 33, line 1, corresponding to paragraphs [0239] - [0240] of the published application:

Quintessence Carrier-Phase Combination

$$\varphi_{Q_1} = \vec{a}_{Q_1}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix} = \begin{pmatrix} a_{Q_1,1} \\ a_{Q_1,2} \\ a_{Q_1,3} \end{pmatrix}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \end{pmatrix} \tag{0.17}$$

the coefficients are defined by:

$$\begin{pmatrix} a_{Q_1,1} \\ a_{Q_1,2} \\ a_{Q_1,3} \end{pmatrix} = \begin{pmatrix} \frac{1}{\lambda_1} & \frac{1}{\lambda_2} & \frac{1}{\lambda_3} \\ -\frac{\lambda_1}{\lambda_1^2} & -\frac{\lambda_2}{\lambda_1^2} & -\frac{\lambda_3}{\lambda_1^2} \\ 1 & 1 & 1 \end{pmatrix}^{-1} \cdot \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \tag{0.18}$$

The Quintessence carrier-phase combinations for the case of four carrier frequencies are given at page 35, line 10 – page 36, line 6, corresponding to paragraphs [0255] - [0257] of the published application:

Quintessence Carrier-Phase Combinations

For k=1:

$$\varphi_{Q_1} = \vec{a}_{Q_1}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \end{pmatrix} = \begin{pmatrix} a_{Q_1,1} \\ a_{Q_1,2} \\ a_{Q_1,3} \\ a_{Q_1,4} \end{pmatrix}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \end{pmatrix} \quad (0.19)$$

the coefficients are defined by:

$$\begin{pmatrix} a_{Q_1,1} \\ a_{Q_1,2} \\ a_{Q_1,3} \end{pmatrix} = \begin{pmatrix} \frac{1}{\lambda_1} & \frac{1}{\lambda_2} & \frac{1}{\lambda_3} \\ -\frac{\lambda_1}{\lambda_1^2} & -\frac{\lambda_2}{\lambda_1^2} & -\frac{\lambda_3}{\lambda_1^2} \\ 1 & 1 & 1 \end{pmatrix}^{-1} \cdot \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \quad (0.20)$$

$$a_{Q_1,4} = 0 \quad (0.21)$$

For k=2:

$$\varphi_{Q_2} = \vec{a}_{Q_2}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \end{pmatrix} = \begin{pmatrix} a_{Q_2,1} \\ a_{Q_2,2} \\ a_{Q_2,3} \\ a_{Q_2,4} \end{pmatrix}^T \cdot \begin{pmatrix} \phi_1 \\ \phi_2 \\ \phi_3 \\ \phi_4 \end{pmatrix} \quad (0.22)$$

the coefficients are defined by:

$$\begin{pmatrix} a_{Q_2,1} \\ a_{Q_2,2} \\ a_{Q_2,3} \\ a_{Q_2,4} \end{pmatrix} = \begin{pmatrix} \frac{1}{\lambda_1} & \frac{1}{\lambda_2} & \frac{1}{\lambda_3} & \frac{1}{\lambda_4} \\ -\frac{\lambda_1}{\lambda_1^2} & -\frac{\lambda_2}{\lambda_1^2} & -\frac{\lambda_3}{\lambda_1^2} & -\frac{\lambda_4}{\lambda_1^2} \\ 1 & 1 & 1 & 1 \\ a_{Q_1,1} \cdot \sigma\phi_1^2 & a_{Q_1,2} \cdot \sigma\phi_2^2 & a_{Q_1,3} \cdot \sigma\phi_3^2 & a_{Q_1,4} \cdot \sigma\phi_4^2 \end{pmatrix}^{-1} \cdot \begin{pmatrix} 0 \\ 0 \\ 1 \\ 0 \end{pmatrix} \quad (0.23)$$

Declaration Under 37 CFR §1.132

Submitted with this paper is a Declaration Under 37 CFR §1.132 of Dr. Nicholas Charles Talbot which leaves no doubt as to compliance with the enablement requirement of 35 USC §112, first paragraph.

At or about the time the application was filed, Dr. Talbot was given the description of the invention contained in the patent application and was tasked with implementing and testing the filters described therein, including the "Quintessence filters." Given the description of the filters contained in the patent application and given no additional information relating to the filters, Dr. Talbot was able to implement the filters for testing purposes and to successfully test the filters using simulated three-carrier GNSS data.

Conclusion

Withdrawal of the rejections under 35 USC §112, first paragraph, is respectfully requested. The application as amended is now believed to be in condition for allowance. An early indication of allowability is respectfully urged.

Respectfully Submitted,

April 25, 2008

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